Evaporation from a Seepage Face

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RESEARCH OBJECTIVES

Dripping of water into waste emplacement drifts may critically affect the integrity of waste packages and the mobilization of radionuclides. To characterize seepage from fractured rocks, we release water from boreholes drilled above an underground opening, and collect it as it drips into the cavity. These seepage data are often influenced by evaporation effects caused by drift ventilation.

The objectives of this research are (1) to understand the evaporation mechanism at a rock surface, (2) to study the coupling between near-surface flow in fractured rock and evaporation, (3) to examine the effect of evaporation on seepage, (4) to develop effective simulation capabilities for unsaturated flow and seepage under evaporative conditions, (5) to analyze evaporation and liquid-release experiments, and (6) to predict seepage into ventilated waste emplacement drifts.

APPROACH

The research objectives are achieved by (1) monitoring relative humidity and ventilation conditions, (2) measuring evaporation potential, (3) observing wetting patterns at the drift ceiling during liquid-release tests, (4) implementing an evaporation boundary condition into an unsaturated flow simulator, (5) calibrating the model against evaporation and seepage data, and (6) using the calibrated model to estimate total evaporation rates and relating them to other terms affecting seepage.

ACCOMPLISHMENTS

We incorporated evaporation effects into the numerical simulator by modeling them as a saturation-dependent Fickian diffusion process. The evaporation boundary-layer thickness was then estimated based on data from free-water evaporation experiments conducted under known relative humidity, temperature, and ventilation conditions. A three-dimensional, heterogeneous fracture continuum model was developed to simulate liquid-release tests. The figure shows the saturation distribution under natural percolation conditions. Despite continuous downward flow of water, a dryout zone develops around the cavity (caused by the reduced relative humidity in the opening), preventing seepage from occurring and affecting the onset of dripping once water is injected from the borehole. The transient release of water from the borehole was simulated along with time-dependent changes in relative humidity. Seepage-relevant parameters were estimated by calibrating the model against the cumulative seepage amount observed in the opening. The modeling results indicate that evaporation effects in a ventilated tunnel are significant, i.e., they have to be accounted for during model calibration and predictive calculations.

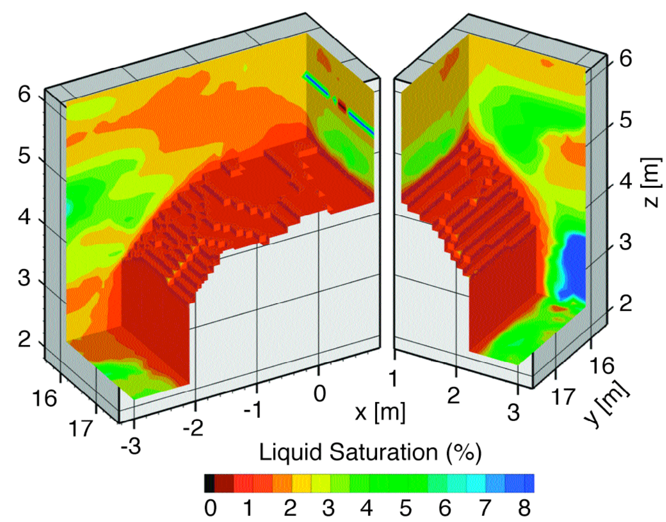

Figure 1. Saturation distribution around a ventilated underground opening, showing the dryout zone caused by evaporation effects

SIGNIFICANCE OF FINDINGS

Compared to previous models that neglected the effect of evaporation, this new approach shows significant improvement in capturing observed seepage fluctuations into ventilated underground openings. Accounting for evaporation effects reduces the potential bias in the estimation of seepage-relevant parameters. It also allows for a better understanding of the mass balance during liquid-release tests, and thus provides more confidence in the use of the calibrated model for simulations of seepage under different ventilation conditions.

RELATED PUBLICATION

Ghezzehei, T., S. Finsterle, and R. Trautz, Evaluating the effectiveness of liquid diversion around an underground opening when evaporation is non-negligible. Proceedings of the TOUGH Symposium 2003, Berkeley, California, May 12–14, 2003.

ACKNOWLEDGMENTS

This work was supported by the Director, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, through Memorandum Purchase Order EA9013MC5X between Bechtel SAIC Company, LLC, and the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab). The support is provided to Berkeley Lab through U.S. Department of Energy Contract No. DE-AC03-76SF00098.